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CSERIAC GATEWAY

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In this issue:

CSERIAC is a United States Department of Defense information analysis center hosted by the Harry G. Armstrong Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio, and operated by the University of Dayton Research Institute.

USAF INSTRUMENT FLIGHT STANDARDIZATION

Kevin Burns

Instrument-related factors have been involved in an alarming number of recent United States Air Force (USAF) aircraft mishaps. As a result, a field team led by the USAF Instrument Flight Center was established by the USAF Inspector General to visit selected Air Force and contractor sites and observe the newest aircraft cockpit designs (e.g., C-17, B-2). The team was assigned to look at cockpit flight instrument standardization among aircraft and each design's usefulness to the operator, from a human factors perspective.

At the conclusion of their field visit, the team prepared a report ("Study on USAF Instrument Flying Standardization," 1989) for the Chief of Staff of the Air Force that included recommendations for cockpit design, procedures, and training. The following discussion will address findings made by the field team, as well as some of their recommendations for cockpit standardization.

Cockpits have changed substantially in the past two decades from highly standardized, dedicated instrument systems to highly missionized, multifunction display suites. The role of the pilot has changed from primarily flying the airplane to performing a multitude of mission-oriented avionics tasks throughout the entire mission.

With limited real estate available in the cockpit and avionics being added to perform increasingly complex

Standardization, on page 2

Standardization, from page 1
missions, dedicated flight instruments have been replaced. Their replacement includes electronic flight instruments that are timeshared with other mission avionics displays.

The design process used by the USAF Aeronautical Systems Division (ASD) has also changed during this period. Historically, cockpits were built using detailed design specifications. ASD now designs missionized cockpits using performance specifications and teams of operational users called Cockpit Working Groups (CWGs).

The result has been a substantial increase in weapon system effectiveness due to the flexibility provided by programmable displays. Unfortunately, this increased effectiveness has been at the expense of standardization, and efforts at standardizing electronic cockpits have trailed the rapid pace of technology.

Research needed to aid in the standardization of electronic cockpits has not been accomplished due to lack of time, money, human resources, and high-fidelity simulation needed to support this type of effort. The inability to accurately define and measure human performance has also been a limiting factor.

Rather than issues of standardization, the focus has been on individual aircraft programs. The cockpit design and development process has changed from the use of well-understood standard design specifications to the use of performance-oriented specifications based on mission analyses (these mission analyses vary significantly from program to program).

The lack of a clear standard for cockpit design has resulted in designs that are dependent upon the mission of the aircraft, the individual members of the cockpit working group, and the contractor's staff.

These dramatic changes in the way crew stations are acquired led the field team to make several recommendations regarding today's current approach to crew station design. Following is an outline of some of the recommendations made by the field team.

Field Team Recommendations

Instrument Flight Symbology. The field team recommended a standard be developed for USAF instrument flight symbology, terminology, and mechanization for both head-up and head-down displays. The report also stated, "The standard should address the use of the head-up display (HUD) as a primary flight reference and the presence of a prominent, centrally located primary attitude display."

Cockpit Working Groups (CWGs). Since there is a CWG established for each aircraft program, the team recommended a training program be developed for CWGs. Progress has been made toward establishing a CWG training program, handbook, database, and proposed regulation.

The CWG training program, according to the field team, should include the role and responsibility of the CWG, current research and development programs related to cockpits, human factors training, and lessons learned from other cockpit developments.

The CWG handbook will be distributed to CWG members in the training program and includes a copy of the regulation, a model CWG charter, guidance on how to operate a CWG, lessons learned from previous CWG activities, CWG activities as a function of program phase, CWG training needs, and a questionnaire addressing the adequacy of the CWG training program.

The CWG database is a hypercard program designed to assist CWGs by informing them of cockpit issues being addressed by other CWGs. It is anticipated that this database will also facilitate the update of cockpit standards, ensure electronic display design precedents are maintained, and facilitate updates of the CWG handbook and training program.

The CWG regulation is being proposed as an Air Force regulation. It is currently in the review and approval process. The regulation establishes the policies and procedures for the incorporation, objectives, organizational responsibilities, membership, and operation (scope, authority, and procedures) of CWGs. It should be noted that this regulation ensures USAF Instrument Flight Center participation in aircraft development/modification programs.

Simulation. The field team observed a general correlation between the amount of operational user interaction and the "quality" of the cockpit. Because of the complex system integration issues involved in modern cockpits, the early and proper use of simulation to develop and evaluate the cockpit has become absolutely critical.

Their recommendation was to "Emphasize the use of simulation and operational users in the development and evaluation of new cockpits." The scientific community must also determine acceptable levels of human performance in the cockpit. A particular set of workload measures and human performance levels should be used as criteria to determine whether a cockpit design is considered acceptable.

Coupled Precision Approaches. The report stated, "In the past 14 years, over half of instrument-related mishaps have occurred at night, while less than 10% of flying is at night. Actual instrument conditions, night weather situations in particular, demand special consideration."

A coupled precision approach capability (coupling the instrument flight director with the autopilot) would "reduce potential for task saturation, allow the pilot to better divide his focus among the multiple tasks required in lieu of channelizing attention on a single task, and aid precision flying." The team recommended that, where compatible, aircraft be equipped with the capability to fly coupled precision approaches.

Runway Lighting. Several recent aircraft mishaps indicate that some runway lighting systems and associated operating procedures do not clearly define the landing environment, and in fact may create visual illusions. Runway approach lighting systems should provide important visual cues during

the critical approach and landing phase of flight. Research into improved runway lighting was suggested by the field team.

Simulation and Aircraft Testing of Instrument Standards. New displays, both head-up and head-down, have often been designed from an employment and engineering point of view. Consideration of instrument flying and spatial orientation is often not given. According to the field team, there is now sufficient experience with these displays to improve their instrument flying capabilities.

Research should identify and validate improved displays and symbologies through simulator and aircraft evaluations. The recommendation made by the field team was for required simulation and aircraft testing of potential cockpit and HUD instrument standards.

Global Positioning System. The Global Positioning System (GPS) is a space-based positioning, navigation, and time distribution system designed for worldwide military use. Passive to the user, spherical accuracy will be 16 meters or better.

Since GPS will be used by all military aircraft, this system needs to be properly integrated into military platforms to enhance system operational performance and to maximize cost effectiveness. The report stated, "Correct integration must ensure that GPS capability and data can be displayed on cockpit flight instruments, will utilize current/familiar formats to display instrument flight information, and can emulate established TACAN, VOR, and ADF procedures."

The field team recommended that a GPS performance standard be established for all military aircraft, a minimum aircrew display GPS format be defined for DOD platforms, and system integrity for use in the National Aerospace System be ensured.

Training. Traditional instrument training has been characterized and reinforced by standard instrument design, cockpit layout, and pilot procedures. T-38 flight training can develop basic instrument skills for use in all fighter, bomber, tanker, and transport aircraft. Changes in cockpit design, evident in the F-16, F-15E, B-1, B-2, and C-17, have increased the difficulty of a smooth transfer of these skills from pilot training to operational employment.

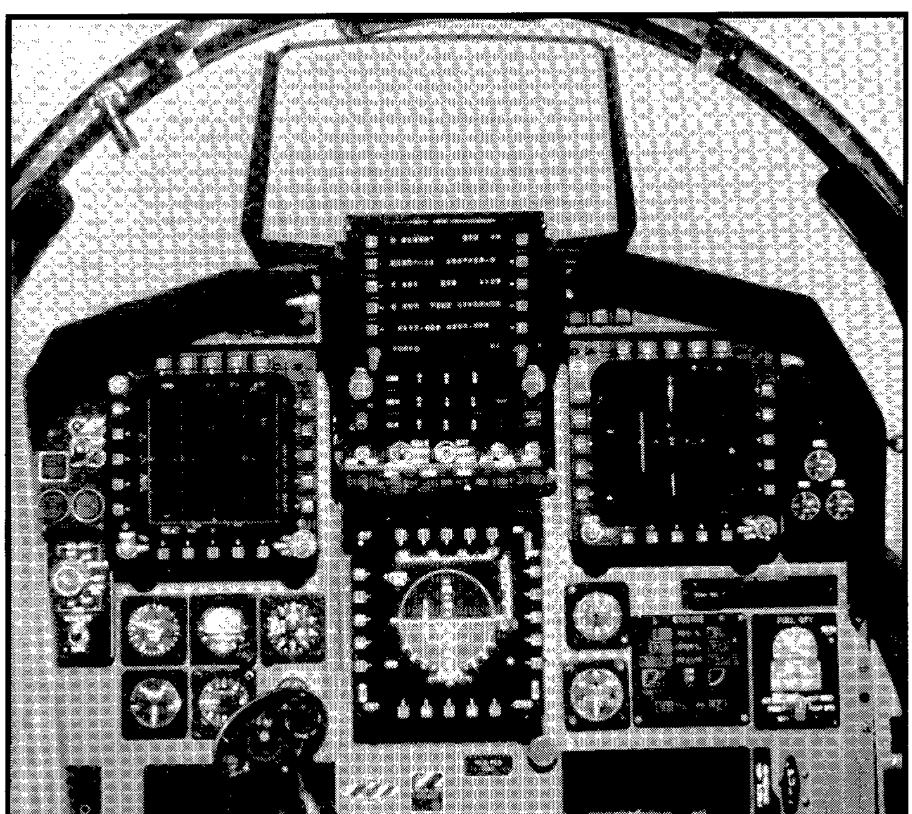
The report stated, "Instrument proficiency is dependent on numerous factors, all of which are reinforced by actual instrument flight." The field team noted that opportunities for actual instrument flight are not sufficient because 1) most formal training is conducted in traditionally good weather areas, 2) bad weather, which precludes mission training, normally results in cancellation and rescheduling of missions rather than generating dedicated instrument profiles, and 3) there are increased concerns over pilot experience and peacetime safety considerations.

Because of limited opportunities for actual weather instrument flight, good simulation is necessary to maintain pilot proficiency and confidence. Thus the field team recommended that current and future simulators should support realistic instrument flight training to include visual capability for simulating transition to landing from weather approach conditions, timely delivery with aircraft, and currency with aircraft software and equipment modifications.

C-17 Aircraft. The field team received presentations from Douglas Aircraft Company regarding the instrument and mission flight requirements for the C-17 aircraft. The report stated, "Several unique features are being considered for incorporation that represent significant departure from what have become accepted and/or standard requirements in cockpit instrument displays and HUD mechanization."

For these reasons, the team recommended that the C-17 cockpit be extensively evaluated via simulation using human factors experts and mission pilots with a wide cross-section of flight, instrument, and Head-Up Display experience.

Standardization, on page 11



The Committee on Human Factors: A National Resource

Harold P. Van Cott

Where can you get objective, comprehensive, state-of-the-art advice from world-class experts on crew systems problems? One source is the Committee on Human Factors of the National Research Council, a working arm of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

Organized in 1980 as a standing committee by the National Research Council (NRC), at the request of Army Research Institute (ARI), Air Force Office of Scientific Research (AFOSR), and Office of Naval Research (ONR), the Committee on Human Factors advises the federal government on a wide range of human factors issues.

The mission of the Committee is to provide new perspectives on theoretical, methodological, and practical issues concerning the relation between individuals/organizations and technology; to assess and propose solutions to critical problems in the design and operation of new systems; and to specify research needed to expand the scientific and technical basis for designing new systems that support human requirements.

One of the major strengths of the Committee is its ability to build bridges between basic research and applications. The Committee carries out its mission through various working groups, steering groups, or panels, which are tasked with specific studies.

Committee Members

Members of the 15-person Committee are appointed for three-year terms. They are carefully chosen from the scientific and engineering community to achieve a full range of expertise and perspective needed to examine an issue or problem from all sides.

Membership of the Committee and its panels is usually multidisciplinary, drawing on the fields of psychology, engineering, sociology, computer science, economics, political science, and other specialties as needed for a given study. Members serve without compensation except for expenses incurred in attendance at meetings.

Projects and Products

As its sponsorship grew from three federal agencies in 1980 to ten in 1990, the activities of the Committee expanded to encompass a wide variety of fundamental and applied issues. Today, the Committee responds to the requests of its sustaining sponsors and to other public and private organizations by providing advice on various human factors issues (e.g., human-computer interaction, multi-colored displays, modeling of pilot vision and cognition).

Projects undertaken include those of interest to the Department of Defense and the services, as well as those of other agencies. Ideas for projects may originate from the Committee itself, from suggestions made by representatives of the Committee's funding agencies, or from requests made by other federal agencies.

The Committee on Human Factors, like other NRC committees, does not do empirical research. All projects are done under grant or contract on a sole-source, non-competitive basis.

The products of the Committee have taken many forms ranging from day-long meetings (one-day symposium by world-class experts, short three-meeting workshop on a special topic) to intensive multi-year studies (human factors research needed to help enhance nuclear power plant safety, human factors considerations in a computer-aided design facility). The work of the Committee and its panels almost always culminates in a report or book available to the public.

Several recently completed studies illustrate the kinds of projects undertaken by the Committee. Two of these projects centered on human performance modeling.

The first was done as a special study in support of the Army/NASA advanced helicopter program. The status of computational models of human vision and cognition was examined to evaluate their use as a model of pilot performance to be used as a driver of a computer-aided design and engineering process. The second modeling report reviewed the characteristics, status, usability, and validity of a variety of existing quantitative models of human performance in complex dynamic systems.

Another recent study examined problems that can occur when several geographically dispersed individuals must make conjoint decisions. This process, called distributed decision making, has been associated with a number of recent accidents. The goal was to strengthen our understanding of the process and the ability to effectively and safely manage distributed decision making. The Committee reviewed literature on the behavioral and cognitive aspects of distributed decision making and outlined proposed research.

Early this year the Committee released a report on human factors issues associated with an aging population. Supported in part by funds from the National Institute on Aging, this study examined issues such as problems with transportation, working, and indepen-

dent living. Proposals for research were made which could increase the quality of life of the aging American population.

The Future

Following are sketches of some of the projects being planned by the Committee: human error at the individual, crew, and organizational levels; linkages between individuals and organizational performance; the augmentation of human intellectual functioning by computer; human factors approaches to enhancing the employability and performance of physically and cognitively handicapped persons in information work; pilots' use of spatial information in navigation and flight control and ways in which this information might lead to principles for new display designs; and a revision of the *Research Needs in Human Factors* (a report published by the Committee shortly after it was formed, and subsequently used as a basis for setting the Committee's agenda).

The ability of the National Research Council to call upon world-class scientists and engineers to volunteer their expertise without cost, the careful process of choosing and melding them into productive teams, and the thoroughness of review to which every report is subjected, are without parallel in the United States or any other nation. These features make the Committee on Human Factors a unique national resource. ●

Harold P. Van Cott is Study Director for the Committee on Human Factors at the National Academy of Sciences/National Research Council.

Readers are invited to submit article proposals, comments, and suggestions to: CSERIAC Gateway Editor, AAMRL/HE/CSERIAC, Wright-Patterson Air Force Base, OH 45433-6573; (513) 255-4842, Autovon 785-4842

THE COTR SPEAKS

Maj. (Lt. Col. Select) Philip Irish, III

We believe this edition of the Gateway has a particularly wide variety of timely ergonomics articles. Our lead story deals with a current ergonomics research initiative being undertaken in the Air Force. This research effort is intended to help eliminate aircraft accidents caused by pilot error resulting from non-standard crewstation designs.

In this edition we also include the third article of a three-part series detailing the services' manpower, personnel, training, and safety (MPTS) programs: first, we reported on the Army's MANPRINT, second, the Navy's HARDMAN, and this time we discuss the Air Force's IMPACTS. Owing to the importance of the current Department of Defense Management Review (DMR) activities, these programs will have much to say about the future of human factors engineering in the three services.

Showing further this edition's diversity, we include a brief article describing the use of hypertext technology in crew system applications. All these articles are provided in addition to our regular features about current happenings at CSERIAC: your one-stop shopping place for crew system ergonomics information.

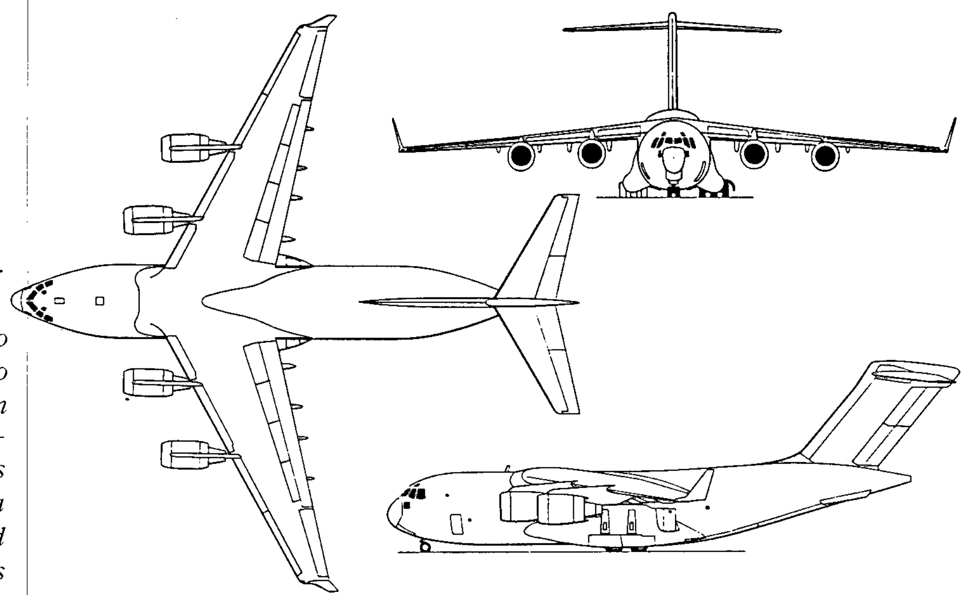
Since our last edition was published, CSERIAC has undertaken a major new initiative in support of the human factors engineering community. CSERIAC has become the official "host" for all future DoD Human Factors Engineering Technical Group meetings. The Technical Group has been meeting semi-annually since 1977 as a forum for the interchange of human factors engineering technical information among bench-level scientists.

CSERIAC is very pleased to be able to support this distinguished body of ergonomics researchers and practitioners from the tri-services and NASA. We believe CSERIAC is uniquely capable of providing the kind of continuity, stability, and well-developed support structure these meetings require. ●

IMPACTS: People Make the Difference

Major Elaine Howell

It takes five specialists to do the seven tasks required to change the battery in an F-4: (1) an armament specialist to disarm the ejection seat, (2) an egress specialist to remove the seat, (3) a maintenance specialist to remove and replace the dead battery, (4) an egress specialist to replace the seat, (5) an armament specialist to rearm the seat, (6) a life support specialist to ensure that the seat and parachute are properly reconnected, and (7) a quality control expert to check the work.



C-17A long-range heavy lift cargo transport

Because of these and other similar problems, the Air Force implemented a new program to increase emphasis on human systems integration in defense systems design. The Integrated Manpower, Personnel, and Comprehensive Training and Safety (IMPACTS) program was implemented by the Air Force to ensure that human systems issues are effectively addressed throughout the acquisition process.

One-third to one-half of every dollar spent during the life-cycle of an Air Force system goes to manpower, personnel, and training. It became clear in the early 1980's that the Air Force approach to human factors integration needed improvement.

Studies and inspections from both the military and private sectors found that manpower, personnel, training, and safety (MPTS) planning was fragmented and ill-timed, and human systems integration was often considered far too late in the process to influence design and be cost-effective. IMPACTS offers potential multi-billion-dollar savings by ensuring more effective design of systems and more efficient use of our human resources.

The B-1B Bomber's fuel tanks are sealed with a gel-type sealant which must be periodically replaced to avoid fuel leaks. Due to the B-1B tank size, this internal tank maintenance must be performed by fuel specialists who are 5'4" or smaller. It is not surprising that there aren't many fuel specialists in the Air Force under 5'4". To avoid a huge military personnel management problem, the maintenance is performed by contractors. This problem was identified only after the initial prototype was built.

The initial objective of IMPACTS is to open lines of communication between subject-matter experts within the "elements" of Manpower, Personnel, Training, Safety, Human Engineering, and Health Hazards Analysis. Communication, coordination, and analysis at every stage of the acquisition constitute the basic architecture of the IMPACTS program.

IMPACTS encourages early analysis, broadens the support focus beyond logistics, and drives MPTS planning towards a more horizontal, less stovepiped, management approach. The organizational solution does not include the creation of new positions at the using commands, nor does it require significant additional person-hours or reporting.

The ultimate IMPACTS goal is to maintain or increase combat capability while reducing aggregate manpower, personnel, and training life-cycle costs, without compromising system safety or creating unjustified health hazards.

Originally the C-17, the Air Force's new heavy-duty airlifter, had a three-person ground refueling crew. Three people were required because the fuel boost pump switches were in the aircraft cockpit. One person had to sit in the cockpit during refueling just to operate the switches. In an emergency, the ground crew would be dependent upon a speedy reaction from the member in the cockpit to turn the switches off.

When the switches were relocated to the wheelwell, a safer, two-person action resulted. Consequently, there was an increase in safety, and decrease in human resources needed. But if the problem had been identified

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TECHNICAL SUMMARY and ANALYSIS SERVICES

CSERIAC provides a variety of products and services to help you incorporate ergonomics principles in the design and operation of human-machine systems. One of these services is providing answers to technical inquiries about ergonomics issues. During our start-up period, CSERIAC has provided this on a cost-free trial basis to all qualified customers. Your overwhelmingly positive feedback indicates your satisfaction with the quality of our service; obviously CSERIAC is providing money- and time-saving answers to your ergonomics problems. However, since CSERIAC must operate on a cost-recovery basis, we will, beginning 1 October 1990, charge a fee for our responses to your technical inquiries. The cost will depend on the level of assistance required to answer your question. To help you understand this fee plan, we will begin by explaining the term "technical inquiry" and the types of responses we can provide.

What Is a Technical Inquiry ?

Simply stated, a technical inquiry is a request for ergonomics information. In general, ergonomics information is technical knowledge about human abilities and performance, which can be used to enhance equipment design and development.

CSERIAC's answers to inquiries can take many forms, including customized bibliographic searches, review and analysis of research, recommendations based on analyses, and expert consultation referrals. CSERIAC can quickly respond to technical inquiries through in-house literature reviews and contact with subject-matter experts. In addition, when answers to questions are not readily available, CSERIAC can bring subject-matter experts together in workshops to address specific issues. CSERIAC can also provide in-depth critical reviews, technical assessments, and state-of-the-art reports. Each of these responses involves varying levels of time and effort, which must be reflected in our fees.

We have grouped these responses into three basic categories, based on the kind and amount of ergonomics expertise applied to the problem. The three categories are **Search and Summary, Review and Analysis,** and **Special Tasks**. A fixed fee has been established for the first two; Special Tasks must be negotiated on an individual basis.

Search and Summary

Search and Summary consists of a literature search and a printout of relevant abstracts. A professional human factors analyst reviews the abstracts and identifies the most pertinent. The human factors analyst also consults references within CSERIAC's immediately accessible resources and provides comments and/or copies of relevant documents. The main purpose of this level of response is to provide a very rapid response to requests for technical information.

Review and Analysis

This level of response includes all of the above plus direct contact with subject-matter experts, a 2-to-5-page white paper synthesizing the results of the technical review, complete copies of references, and names, addresses, and telephone numbers of subject-matter experts. It also includes the requisite materials for access to databases and personal contact with the subject-matter experts. The main purpose of this level of response is the in-depth synthesis of the literature with the formation of an authoritative "conclusion" or answer regarding the question posed.

Special Tasks

In this category are those inquiries requiring major CSERIAC time and material expenditures, such as preparation of SOARs and handbooks, organizing workshops and symposia, or exercising computer models in our Technology Transfer inventory. The main purpose of this level of response is an extensive customized effort directed at solving the requester's particular needs.

Who Can Request Technical Summary and Analysis Services?

Subscription accounts can be established by organizations in the Department of Defense (DoD), by other government agencies, as well as by contractors. Academic and corporate users, in both domestic and international markets, can establish accounts. (Products/services will be provided to these users based on DoD security guidelines.)

Why Should I Come To CSERIAC For This Service ?

1. CSERIAC can help you formulate more precise questions before seeking complex technical answers;

2. CSERIAC can search many, many information sources and acquire the customized answers you need at very low cost and with rapid turnaround. [CSERIAC has priority access to many governmental databases.] Most inquiries are answered within two days to two weeks.

3. CSERIAC has ready access to a worldwide network of subject-matter experts who can aid in solving your problem or answering your question. These experts also serve as a peer review pool to assist in verifying our responses to your queries.

4. CSERIAC is committed to excellence in customer service. Hence, we can confidently offer a **SATISFACTION GUARANTEE.** If you are not satisfied with the quality of our product, we will fix the problem or credit your account.

What Is The Cost Of This Service?

For inquiries at the **Search and Summary** level CSERIAC will charge $975 each. This fee is based on the average cost of providing this level of effort in the past.

When the more extensive effort of a **Review and Analysis** response is required, the cost-recovery fee is $4975.

In the case of **Special Tasks** CSERIAC will estimate the total time and materials required, and discuss cost with the requester individually.

What Methods Of Payment Are Available?

A convenient way is to open a debit account, against which the costs of services or products are subtracted. A minimum of $1000 and a maximum of $300,000 can be placed in this account at any one time. Funds placed in such a "subscription" account can be used for up to two years and additional funds can be added at any time. The greatest advantage of this accounting system is in time savings to you. Requests for products and services can be undertaken immediately without lengthy delays or reviews.

CSERIAC services can be purchased by check, purchase order, MasterCard, or VISA. With qualified industrial accounts, we can respond to technical inquiries and bill for later payment (net 30 days). Please make checks and purchase orders payable to the **University of Dayton**.

Search and Summary Example #1

An engineer at a major research and development corporation requested information on the effects of rapid "explosive" decompression on human performance and physiology. He was responding to the Federal Aviation Administration in an effort to study the effects of decompression resulting from a hole created in the fuselage (e.g., from a terrorist bombing) during high-altitude flight. We performed bibliographic searches of many databases including: Defense Technical Information Center (DTIC), National Aeronautics and Space Administration (NASA), Transportation Research Information Service (TRIS), and the Armstrong Aerospace Medical Research Laboratory Biodynamics Data Bank. CSERIAC then summarized the performance and physiological effects that such an event would cause, and provided specific recommendations to them for the appropriate and immediate life support action that should be taken to maintain effective crew performance.

Search and Summary Example #2

A scientist at a military research center requested information about workload assessment tools for determining the appropriate crew size for the Navy's AH-1W Cobra helicopter. We recommended using one of these analytical techniques: the Modified Cooper-Harper Scale, Subjective Workload Assessment Technique (SWAT), or NASA Task Load Index (NASA TLX). We summarized the construction, methodology, strengths, and weaknesses of all these techniques and provided references to past research where they were used. We also put her in contact with an internationally recognized expert in workload assessment. Finally, we contacted the Defense Training and Performance Data Center to find the location of two AH-1W Cobra simulator sites.

Review and Analysis Example

An engineer from a military research and development facility asked about color coding standards for use in scalar displays. First, a search of literature databases was accomplished. The results provided to the requester included over 100 pertinent abstracts along with annotations of those which were most relevant. Several hard-copy reports of these abstracts were provided.

Next, CSERIAC contacted several nationally recognized experts to solicit their views. The requester was provided with the names, organizations, and telephone numbers of these experts.

CSERIAC also researched journal articles, reference materials and design standards to identify references bearing on the problem. CSERIAC included in the package excerpts from some of these references. Many excerpts came from an excellent publication that CSERIAC offers for sale: ***Engineering Data Compendium: Human Perception and Performance*** by Boff and Lincoln.

Finally, CSERIAC distilled information from several major guidelines. Two of the best standards for this technical inquiry were: the NASA Man-Systems Integration Standard, NASA-STD-3000, Mar 87, and the Society of Automotive Engineers Aerospace Recommended Practice, ARP4032, APR 88. The relevant portions of both these standards were provided to the customer. Other standards specifically researched were: MIL STDs 1472, 1794, 411, and 250.

The following narrative summarizes the technical answer that was provided to the customer. The NASA and ARP standards were primarily directed towards CRT displays, but appeared to have significant relevance for other display technologies as well. These references advise designers that to determine the correct method for applying color coding one needs to: 1) carefully assess the specific display characteristics for the proposed hardware, 2) consider the operator's perceptual capabilities, and 3) establish the precise nature of the task to be performed.

Color coding is generally recommended as a useful means of assisting operators in searching for and identifying classes of information which remain stable over time. While this is most often associated with the categorization of qualitative kinds of data, it appears it can also be used to portray ranges, conditions, or states of quantitative data as well. The primary advantage touted for using color coding with either quantitative or qualitative data is in its organizing or "chunking" value.

It has been fairly well documented that color coding assists operators both in attracting their attention to information and in their search time for it. However, it appears that the numbers of classes of color-coded information must be restricted [less than 10, and optimally less than 5] so that the color set itself does not become burdensome. Several researchers advise caution about arbitrarily introducing colors into displays, which they believe merely adds chromatic "noise" and consequently can be expected to degrade operator performance.

Color coding can take various forms and can be either fully redundant or partially redundant with other information or codes, i.e., shape or size. A simple example of the fully and partially redundant approaches is shown below:

Quantity to be shown	1	2	3	4	5	6	7
Full	RED	ORANGE	YELLOW	GREEN	BLUE	INDIGO	VIOLET
Partial	RED	RED	YELLOW	YELLOW	YELLOW	GREEN	GREEN

Color coding can also be accomplished using a nominal or an ordinal scheme: in nominal coding each color represents one aspect of the presented information (much like the fully redundant example shown above); while in ordinal the colors are ordered in some fashion to represent an ordered set of data, e.g., as temperature increases, colors shift from "cooler" to "warmer" hues.

Color coding has also been shown to be beneficial in those task domains where the legibility of information is difficult, where task loading or information density is high, where viewing time is constrained and where colors are logically related to the tasks. During task loading and constrained viewing times, it has been shown that color coding can reduce error rates and does not contribute to longer reading times. It is also strongly recommended that there be a clear intuitive relationship between the selected colors and their intended meaning.

The use of color coding is contraindicated specifically when either the ambient illumination conditions degrade the operator's color sensitivity or the operator must wear special vision devices, e.g., night vision devices. If the display will be operated in conditions of direct sunlight or lowered or filtered fluorescent/incandescent illumination, special care must be taken to ensure adequate color sensitivity.

There are a variety of special concerns of which the designer must be aware when considering the use of color coding. First, there is almost universal operator preference for color displays versus monochrome because of their intrinsic aesthetic appeal. However, this is not always accompanied by performance improvements. Task characteristics are important. And of course, it's also critical that the proportion of the operator population which possesses color deficiency problems be considered before deciding to use color coding.

The colors to be selected must also be evaluated for potential interactive effects, i.e., to ensure adequate color contrast. Each characteristic of a color (i.e., brightness, hue and saturation) must be carefully selected to ensure proper contrast. Choosing either a rainbow approach or a full range of one specific hue should be based upon both meaningfulness and discriminability factors. It is also recommended to provide a color reference scale on the display in that these references have been shown in a number of cases to significantly reduce the size of operator errors.

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during design, the change could have been made at far less cost.

IMPACTS is guided by an Air Force-wide colonel-level steering committee, and an Air Staff working group. Both groups are chaired by the Chief Requirements and Organization Division (PRME). The IMPACTS program is supported by a model organization, established in 1986 at Aeronautical Systems Division (ASD), Wright-Patterson AFB, Ohio. Formed under an agreement by the Air Staff, Air Force Systems Command, and Air Training Command, its charter is to develop methods to integrate MPT into the acquisition process. Known as the Directorate for Manpower, Personnel, and Training, or more familiarly as ASD/ALH, they provide expertise on a matrix basis, when and where it is needed within the product division.

The first program to receive MPT analysts from ASD/ALH was the Advanced Tactical Fighter (ATF) System Program Office. A heightened awareness of human systems issues resulted in several significant planning changes.

A training planning team was formed which included manpower and personnel subject matter experts, resulting in the first IMPACTS Planning Team. The planning team produced a training plan a full year-and-a-half prior to full scale development. They also influenced the evaluation of design alternatives such as use of on-board versus off-equipment auxiliary power units; on-board oxygen and nitrogen generating systems; and human resource factors versus system performance, technology and costs. At the bottom line—a system which should be far less manpower intensive than its predecessors.

IMPACTS provides a forum for the experts from each element to understand how each individual plan and process influence the integrated whole, and to evaluate the trade-offs. Integration, viewed in this context, relies heavily upon bringing together functional experts to share ideas and information, and find a balance between naturally interrelated concepts. The working group/planning team concept is vital to IMPACTS implementation.

IMPACTS is applied at the policy and review level by the Air Staff working group. At a milestone review for MILSTAR (a joint program to deploy a series of satellites to relay military communications during wartime), the IMPACTS Working Group challenged the human resource requirements found in the Manpower Estimate Report (MER). A reevaluation of organizational structure, maintenance response times, and operational concept resulted in a savings of nearly 1,000 manpower slots.

Development of a four-tiered IMPACTS training program is now underway. A reference handbook will provide quick assistance in early analysis; available tools, models and databases; and preparation of the Manpower Estimate Report (MER) and supporting documentation to using commands and program offices.

A familiarization course is designed for IMPACTS team members, program office personnel, MAJCOM subject-matter experts, industry representatives, and any others who might be involved in IMPACTS issues. Also in the works is a Senior Executive Seminar, a one-day course designed to attune senior Air Force and industry leaders to IMPACTS issues. An in-depth course for Human Systems Integration Specialists is projected for the future.

For further information on IMPACTS, contact the IMPACTS Office, HQ USAF/PRME, Pentagon, Washington DC 20332, (202) 693-4160, AV 223-4160. ●

RECOMMENDED READING

Ergonomics Sourcebook: A Guide to Human Factors Information. Edited by Kimberlie H. Pelsma. 1987. Lawrence, KS, The Report Store, A Division of Ergosyst Associates, Inc. 276 pages. $72.50.

This volume presents a compilation of human factors information resources including annotated lists of international associations, online databases, research centers, consultants, periodicals, and basic references. The resources are organized around eleven "ergonomics issues," such as information presentation and communication, workplace design, health and safety, test and evaluation, and standards.

As with any collection of this type, the compilation is not exhaustive and may even seem arbitrary at times. Nevertheless, it is representative of the available resources and should prove useful to human engineering professionals.

Available from Ergosyst Associates, Inc., 123 W. Eighth Street, Suite 210, Lawrence, KS 66044-2605, (913)842-7334.

●

1990-1991 Directory of Federal Laboratory & Technology Resources: A Guide to Services, Facilities, and Expertise. Prepared by the Center for the Utilization of Federal Technology, U.S. Department of Commerce, National Technical Information Service. Approx. 350 pages. $59.95.

This Directory is a convenient desktop reference that an engineer, scientist, or decision maker can use to locate over 1100 U.S. Government technology-oriented resources. The resources are arranged in various categories, including aeronautics, biological sciences, computer technology, engineering, manufacturing, medicine and health, military technology, and transportation.

Available from the National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, VA 22161, (703)487-4650, or from Addison-Wesley Publishing Company, Route 128, Reading, MA 01867, (617)944-3700, ext 2621.

CHIEF SCIENTIST'S REPORT

Donald J. Polzella

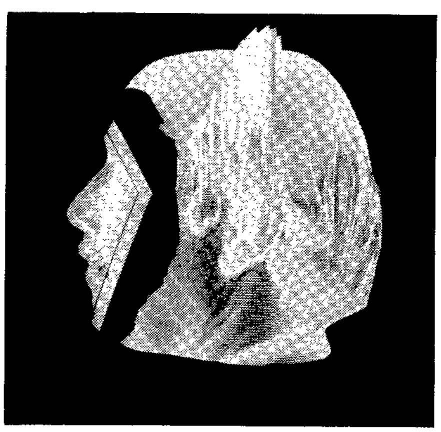
Some people are under the mistaken impression that CSERIAC's services are available only to people affiliated with the tri-services. Although CSERIAC primarily supports the Department of Defense (DoD), its contractors, and other governmental organizations, it is also available to other types of users.

We have provided products and services to academic and corporate customers, at both the domestic and international levels (in accordance with DoD security guidelines and policy regarding the handling of information on military critical technologies).

Following are two examples of technical inquiries initiated by researchers not affiliated with the DoD or the government. In both cases, we were able to use the technical expertise of our host organization, the Harry G. Armstrong Aerospace Medical Research Laboratory (AAMRL).

Non-Invasive Scanning Technologies

As mentioned in previous articles in the Gateway, CSERIAC is actively involved in technology transfer. We received a call from a state of Ohio technology transfer representative who is charged with helping private business interface with government programs. One of his goals is to facilitate the transfer of new and emerging technologies from the government to the private sector. He called CSERIAC to determine whether we were familiar with any new technologies that could help a chiropractor examine a person's posture.



Specifically, the chiropractor was interested in exploring the use of non-invasive surface digitization technologies to study people standing upright. This technology makes it feasible to quickly digitize thousands of surface points on the human body in three-dimensional space, generating a complete numerical definition of the body surface. In the manufacturing arena, this technology may eventually be used to directly cut patterns or produce molds for personal equipment (e.g., g-suits, oxygen masks, gloves).

The chiropractor wanted to develop software that could analyze data obtained from digitizers to facilitate the diagnosis of abnormal alignment of the spine. Data obtained would be fed into a computer, and then analyzed to determine if the parameters were within correct range for normal posture. The obvious advantage of using non-invasive techniques is that clients can be tested for abnormalities of the spine, yet not be bombarded with x-rays.

The chiropractor had been unsuccessful in obtaining information regarding commercially available surface digitizers and had turned to the technology transfer representative for information (who then called CSERIAC). CSERIAC contacted expert network member Kathleen Robinette (AAMRL/Workload and Ergonomics Branch) who is actively involved in the development of surface digitization technologies. Robinette was able to provide us with several points-of-contact for surface digitizers.

Wrist Mobility and Carpal Tunnel Syndrome

A researcher at Kansas State University, Department of Industrial Engineering, was conducting a baseline study of wrist mobility. Females are more subject to carpal tunnel syndrome, and the researcher was trying to determine reasons for this propensity. Do women have more or less flexibility in their wrists than men? Are women employed in occupations that engender greater potential for carpal tunnel damage? Do we lose mobility with aging? Can people increase the flexibility of their wrists?

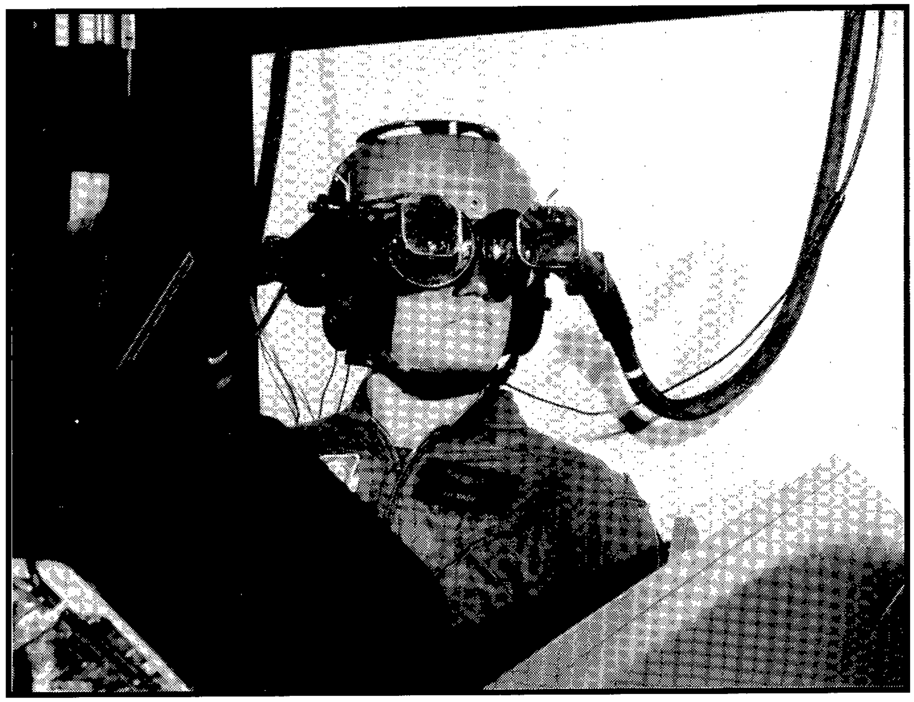
As part of a pilot study, the researcher was attempting to measure wrist mobility of seated subjects. Subjects' arms were immobilized at the elbow and their range of motion was measured. A pen was used to mark the starting point (i.e., where the fingers were), the hand was moved, and then the end point was marked. A goniometer (a protractor with a handle on it) was used to measure the distance traversed. However, this measurement technique appeared to be error-prone.

The researcher contacted CSERIAC to ask if we could offer any advice on better ways to measure wrist mobility. We contacted expert network member Joe McDaniel (AAMRL/Workload and Ergonomics Branch). He told us about several devices available for measuring range of motion (e.g., magnetic device which measures location/ori-

Chief, on page 11

TECHNOLOGY TRANSFER

Subjective Workload Assessment Technique (SWAT)



High technology systems can, at times, place an overwhelming demand on information processing, decision making, and other mental abilities of human operators. Mental workload is a concept that describes the degree to which an operator's non-physical capacities are taxed by a system while the person is attempting to maintain adequate performance.

Measures to quantify workload (both mental and physical) have been developed to provide operations analysts, system designers, and training designers with tools to ensure that missions and equipment are designed within the capabilities of operators.

The Subjective Workload Assessment Technique (SWAT) is a procedure for measuring mental workload which was developed at the Workload and Ergonomics Branch of the Harry G. Armstrong Aerospace Medical Research Laboratory. It is a workload measure with known metric properties and is useful in operational or "real-world" environments.

The workload model defined for SWAT includes three dimensions: time load, mental effort load, and psychological stress load.

Time load refers to the amount of time available for an operator to perform a task. This includes both the overall time and the rate at which the person must work to keep up with the task.

Mental effort load refers to the amount of attentional capacity or effort required by the task, without regard to time. This includes functions such as retrieving information from memory, performing calculations, and making decisions.

Psychological stress load refers to anything that makes the task more difficult by producing anxiety, frustration, and/or confusion. This includes factors such as fatigue, vibration, g-loading, and heat. The effects of the stressors that are included occur prior to their direct interference with task performance.

SWAT has an easily administered subjective scaling method which can be used in cockpits and other operator stations. Relatively unintrusive data collection techniques were chosen for SWAT because of its intended use in these "real-world" environments.

Through conjoint scaling, responses made using simple descriptors for each of the three workload dimensions are converted into scale values for workload. The amount of time required to make responses is minimized because operators need only memorize a limited number of non-complex descriptors.

SWAT uses a two-step procedure to quantify the mental workload associated with various events. In the first step, the scale development phase, hypothetical activities are rank-ordered according to perceived workload. Each activity is specified in terms of a particular distribution of load across the three dimensions. These data are transformed, by means of conjoint measurement, into an interval scale of workload ranging from 0 to 100.

In the second step, the event scoring phase, an activity or event is rated by assigning a value of 1 to 3 on each of the three dimensions. The scale value associated with this combination (obtained from the scale development phase) is then assigned as the workload value for that activity.

SWAT is implemented on an IBM PC or compatible system with a minimum of 512K internal memory, and two floppy disk drives (or one fixed and one floppy drive). An 8087 math coprocessor will speed up the program, but is not necessary for execution. The program can analyze scale development data for up to 30 subjects.

SWAT exists in English, German, and French versions. Copies of the "User's Guide" and Scale Development software are available from CSERIAC for a cost-recovery fee. ●

Hypertext

Few people have heard of hypertext, and even fewer can describe hypertext in terminology understandable to the average person. It is a concept that can best be understood through examples, not through abstract definitions.

Imagine that you have the task of reading through an entire encyclopedia. You might take several approaches. If you choose a linear approach, you will simply open the encyclopedia to the first sentence of the first page of the first volume and read everything in order until you reach the last sentence on the last page. Footnotes and references will be read at the end of each column or section, as they are encountered.

If the encyclopedia is in digital form and incorporates hypertext, however, your approach could be much more flexible. You may start on the first sentence of the first page of the first volume, but you won't necessarily have to read everything sequentially.

For example, as you are reading about aardvarks, you notice a footnote. Instead of waiting until you reach the end of the section to read it, you move directly to the content of the footnote (by touching the screen, clicking the mouse, etc.). Once finished with the footnote (it wasn't very intriguing) you return to your place in the body of the text.

You read that aardvarks are burrowing mammals with hairy, stocky bodies, large ears, long tubular snouts, and powerful digging claws, who feed on ants and termites, and are native to southern Africa. You begin to wonder about the types of ants and termites that exist in that region, so you touch or click on the word Africa and jump directly to the article describing the flora and fauna of that continent.

If you are curious, your trip through the encyclopedia will be full of many such excursions back and forth through all the volumes (using cross references, footnotes, and the names of people, places, and things to link electronically with topics that catch your interest).

Nevertheless, you do manage to read the entire encyclopedia in this nonlinear (i.e., hypertext) fashion. Some might even argue that such a nonlinear approach will result in a more productive learning experience than a strictly linear reading.

Crew System Ergonomics

What does this have to do with human factors or crew system ergonomics? Complex technical material is often multidimensional with many interconnected ideas. Conveying this information with the use of hypertext technology can be more efficient and result in better use of the materials.

For example, the 300,000 pages of documentation required for the F-18 aircraft are organized as hundreds of manuals created by dozens of contractors and subcontractors. Often these aircraft are maintained on the flight line by a maintenance technician who carries the four or five manuals most likely to help in troubleshooting a problem.

Under these circumstances, it is impossible for the maintenance technician to hold a place in one manual and follow cross references to all the other manuals that might be cited, since many of these might still be back at the hangar or maintenance depot. On a portable computer with adequate storage capacity, these physical constraints are irrelevant, and a hypertext user interface can retrieve information that is widely separated on paper and display it as if it were directly connected.

The Paperless Environment

The rapid rise of hypertext as a design concept is due to numerous forces. One major documentation standards effort, the Computer-Aided Acquisition and Logistic Support (CALS) program, is a Department of Defense standards initiative that has emerged as a driving force for hypertext. CALS has as its goal the creation of a "paperless environment" that integrates the various "islands of automation" involved in system design, development, deployment, and maintenance processes.

Initially, government contractors will be required to provide digital versions of system manuals, which will be displayed electronically to users in traditional page-oriented format. These "digital page-turners" will significantly reduce both the need for and the volume of printed information.

The ultimate goal of CALS, however, is for all system specifications, drawings, manuals, and other technical data to be created and delivered in digital form so that complete information exchange and concurrent engineering are supported. When this goal is achieved, information will be designed from the outset without any notion of "pages." The user will receive what has been described as "pageless technical manuals" on electronic media that rely heavily on hypertext concepts.

Conclusions

Hypertext has the potential to increase significantly the accessibility and usability of on-line information for crew system designers, developers, and users. However, much of what has been written about hypertext is hyperbole, and practical advice for designing hypertext capabilities into systems is frequently difficult to find.

The potential of this important new design concept and practical suggestions for planning and implementing successful hypertext projects are described in the state-of-the-art report *Hypertext: Prospects and Problems for Crew System Design,* by Robert Glushko, soon to be published by CSERIAC. ●

This article was adapted by Deborah Licht from the upcoming CSERIAC report.

Standardization, from page 3

Conclusions

A number of Air Force organizations are working together to accomplish the recommendations of the field team. Organizations involved in these efforts include the Air Force Logistics Command, Air Force Instrument Flight Center, and Air Force Systems Command (Aeronautical Systems Division/ Crew Systems Division; Human Systems Division; Air Force Flight Test Center). Many efforts are already in process or completed including the development of a C-17 simulation, creation of a Global Positioning System (GPS) Working Group, update of Air Force Regulation 5-11, evaluation of T-38 Head-Up Display, formalization of Cockpit Working Groups (CWG), update of Military-Standard-1787 (display symbology), and the development of a handbook for pilot-in-the-loop simulations.

Foremost, the Air Force System Command must provide the user with high-quality cockpits, and the multidisciplinary nature of cockpit development requires a broad team effort. This team approach will continue to enhance every phase of cockpit design and system development. ●

Kevin Burns is Technical Specialist in the Crew Station and Escape Branch, Crew Systems Division, Directorate of Support Systems Engineering at Aeronautical Systems Division, Wright-Patterson Air Force Base, Ohio.

This article is adapted from "Study on USAF Instrument Flying Standardization," March 1989, a report prepared for the Chief of Staff of the United States Air Force.

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Chief, from page 8

entation in three-dimensional space; sonic digitizer; bending fiber optics; photographic methods) but that the goniometer is at least as accurate as these methods and much less expensive.

He suggested that the variability they found in their measurements was not a problem with the technique, rather the measurements obtained with the goniometer reflected the variability in the humans being measured. Human movement varies considerably from trial to trial.

Both voluntary and involuntary movement is difficult to duplicate since there really is not an absolute limit to any movement (other than dislocation or breakage). If, for example, subjects are asked to move a body part to its fullest extension, their fullest extension may depend upon effort put forth, amount of pain/discomfort that is bearable, and many other factors. These factors can vary for each subject, each day, and/or each trial. The best that can be done is to take several measurements and use an average measurement to represent wrist mobility. ●

CALENDAR

October 8-12, 1990
34th Annual Meeting of the Human Factors Society, Orlando, Florida. Stouffer Orlando Resort. Theme: "Countdown to the 21st Century." Janet J. Turnage, General Chair; Nancy C. Goodwin, Santa Monica, CA 90406; (213) 394-1811 or 394-9793; fax (213) 394-2410.

November 1-4, 1990
ACM, SIGCHI and SIGGraph symposium on User Interface Software and Technology. Contact Association for Computing Machinery, 11 W. 42nd St., NY 10046; (212) 869-7440.

November 27-28, 1990
NASA's Technology 2000, Washington, DC. Washington Hilton. Contact Technology Utilization Foundation, 41 East 42 St., Suite 921, New York, NY 10017; (212) 490-3999.

Notices for the calendar should be sent to CSERIAC Gateway Calendar. CSERIAC Program Office, AAMRL/HE/CSERIAC. Wright-Patterson AFB, OH 45433-6573, at least four months in advance.

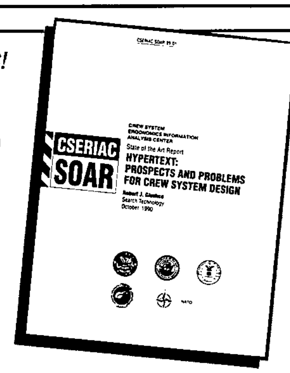
AVAILABLE SOON FROM CSERIAC!

State-of-the-Art Report

HYPERTEXT

Prospects and Problems for Crew System Design

Robert J. Glushko
Search Technology



This informative report reviews the state of the art in the important new field of hypertext, an innovative concept for displaying information on computers that uses nonlinear methods for linking related information. Hypertext can significantly improve the accessibility and usability of on-line information for crew system designers and users. The report discusses:

Definitions and historical context: What hypertext is and why it has recently emerged as an important design concept.

Hypertext applications: How hypertext concepts can be applied in crew system design, including on-line presentation of handbooks, standards documents, software manuals, and maintenance aids.

Hypertext design and technology: The elements of hypertext, and software and hardware to support its implementation.

Hypertext development: Practical advice for designing hypertext capabilities into information systems.

For further information, contact the CSERIAC Program Office.

NEWS FROM the Defense Logistics Agency's

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CSERIAC PRODUCTS AND SERVICES

CSERIAC's objective is to acquire, analyze, and disseminate timely information on crew system ergonomics (CSE). The Domain of CSE includes scientific and technical knowledge and data concerning human characteristics, abilities, limitations, physiological needs, performance, body dimensions, biomechanical dynamics, strength, and tolerances. It also encompasses engineering and design data concerning equipment intended to be used, operated, or controlled by crew members.

CSERIAC's principal products and services include:

• technical advice and assistance;

• customized responses to bibliographic inquiries;

• written reviews and analyses in the form of state-of-the-art reports and technology assessments;

• reference resources such as handbooks and data books.

Within its established scope, CSERIAC also:

• organizes and conducts workshops, conferences, symposia, and short courses;

• manages the transfer of technological products between developers and users;

• performs special studies or tasks for government agencies.

Services are provided on a cost-recovery basis. An initial inquiry to determine available data can be accommodated at no charge. Special tasks require approval by the Program Manager.

To obtain further information or request services, contact:

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